Minimum High Fire Temperatures Detected in AVIRIS Spectral Measurements from Brazil in 1995

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1.0 Introduction

In August and September of 1995 the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) was deployed to Brazil as part of the NASA Smoke Cloud Aerosol and Radiation experiment in Brazil (SCAR-B). AVIRIS measures spectra from 400 to 2500 nm at 10-nm intervals. These spectra are acquired as images with dimensions of 11 by up to 800 km with 20-m spatial resolution. Spectral images measured by AVIRIS are spectrally, radiometrically, and spatially calibrated.

During the SCAR-B deployment, AVIRIS measured more than 300 million spectra of regions of Brazil. A portion of these spectra were acquired over areas of actively burning fires (Figure 1). Actively burning fires emit radiance in the AVIRIS spectral range as a function of temperature. This emitted radiance is expressed from the 2500-nm end of the AVIRIS spectrum to shorter wavelengths as a function of intensity and modeled by the Planck function (Figure 2). The objective of this research and analysis was to use spectroscopic methods to determine the minimum high temperature of the most intense fires measured in the SCAR-B AVIRIS data set.

Spectra measured by AVIRIS with hot sources have been previously examined for volcanic lava (Oppenheimer et al., 1993) and fires in Brazil (Green, 1996).

2.0 Data

AVIRIS measured 300 million spectra of 20 by 20 m spatial resolution for 8,000 km^2 area in Brazil in August and September of 1995. Spectra with actively burning fire are most easily identified by high radiance values in the 2000- to 2500-nm region of the spectrum measured by AVIRIS. The radiance values with burning fires vastly exceed those for reflected sunlight from a target with a reflectance of 1.0. For the more intense fire spectra, portions of the AVIRIS spectral range were saturated at the 12-bit digitization of the signal chain. To identify the most intense fires in the SCAR-B data set, an algorithm was developed to detect AVIRIS spectra that had saturated at the shortest wavelengths. This algorithm was applied to the 100 gigabytes of SCAR-B AVIRIS data.

A number of spectra near Alta Floresta, Brazil (latitude: -9.92, longitude: -55.80) acquired on the 23rd of August 1995 showed saturation of the AVIRIS spectrometers at 1000 nm in the spectral range (Figure 3). The saturation at 1000 nm shows this to be one of the most intense fires in the AVIRIS SCAR-B data set. However, even with this high intensity, at 500 nm wavelength the smoke in the Alta Floresta area dominates the AVIRIS image (Figure 4). At 1000 nm, as predicted by the spectrum, the intense fire is apparent in the upper right quadrant of the image (Figure 5). Also at 1000 nm, other surface features are apparent as some light is transmitted through the smoke particles. At the long wavelength end of the AVIRIS spectrum only the fires are expressed in the AVIRIS image of Alta Floresta on the 23rd of August 1995 (Figure 6). More than 50 fires were burning at the time these data were measured. For this research only the spectra from the most intense fire were analyzed to estimate the minimum high burning temperature.

3.0 Analysis and Results

The radiance of these most intense fire spectra derives from both solar reflected energy and fire emitted energy. To compensate for the solar reflected contribution, the radiance from an adjacent nonburning spectrum is subtracted from the intense fire spectra (Figure 7). This correction removes the scattered solar radiance contributed by the smoke. At 760 nm a small radiance peak is expressed in the spectrum that is attributed to hot oxygen in the in the fire an adjacent air. A simple estimation of the minimum high temperature of this fire is provided by comparing these solar corrected spectra to radiance spectra modeled for hot targets at various temperatures (Figure 8). This comparison leads to a minimum high temperature of 1175 K for these Alta Floresta spectra. This is a conservative estimate because the one-way transmittance of the atmosphere from the fire to AVIRIS has been ignored. Transmittance through the smoky atmosphere greatly reduces the radiance measured by AVIRIS compared to the fire source. To compensate for this transmittance loss, a calculation has been made using the MODTRAN radiative transfer code (Berk et al., 1989; Anderson et al., 1995) (Figure 9). This transmittance correction has been applied to the fire spectra and new Planck function spectra generated (Figure 10). This analysis shows a minimum high temperature of 1450 K. There is considerable uncertainty in this minimum high estimate due to the assumptions required in estimating the transmittance. For these analyses, the area of the burning fire has been assumed to fully fill the AVIRIS 20-m spatial resolution. Continuing research will focus on estimation of transmittance in these smoky atmospheres and assessment for fire area within the AVIRIS spatial resolution. However, both the 1175 K and 1450 K result give an initial range for the minimum high temperature for the fires measured by AVIRIS in Brazil.

4.0 Conclusion

A set of spectra from an extremely intense fire have been identified and extracted from the 300 million spectra measured during the deployment of AVIRIS to Brazil for the NASA SCAR-B experiment. A simple algorithm subtracting the radiance of an adjacent nonburning spectrum has been used to remove the solar-scatter contribution to the fire spectra. Comparison with modeled plank functions gives a conservative minimum high temperature of 1175 K for these spectra of a fire near Alta Floresta, Brazil, on the 23rd of August 1995. With a number of assumptions, the transmittance loss has been calculated and compensated for in these spectra. With this compensation, an estimated minimum high temperature of 1450 K has been derived. Additional work is required to validate and refine the transmittance correction. This research and analysis shows that for the SCAR-B data set, spectra measured by AVIRIS, enable new spectroscopic approaches for deriving properties of actively burning fires.

5.0 References

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6.0 ACKNOWLEDGMENTS

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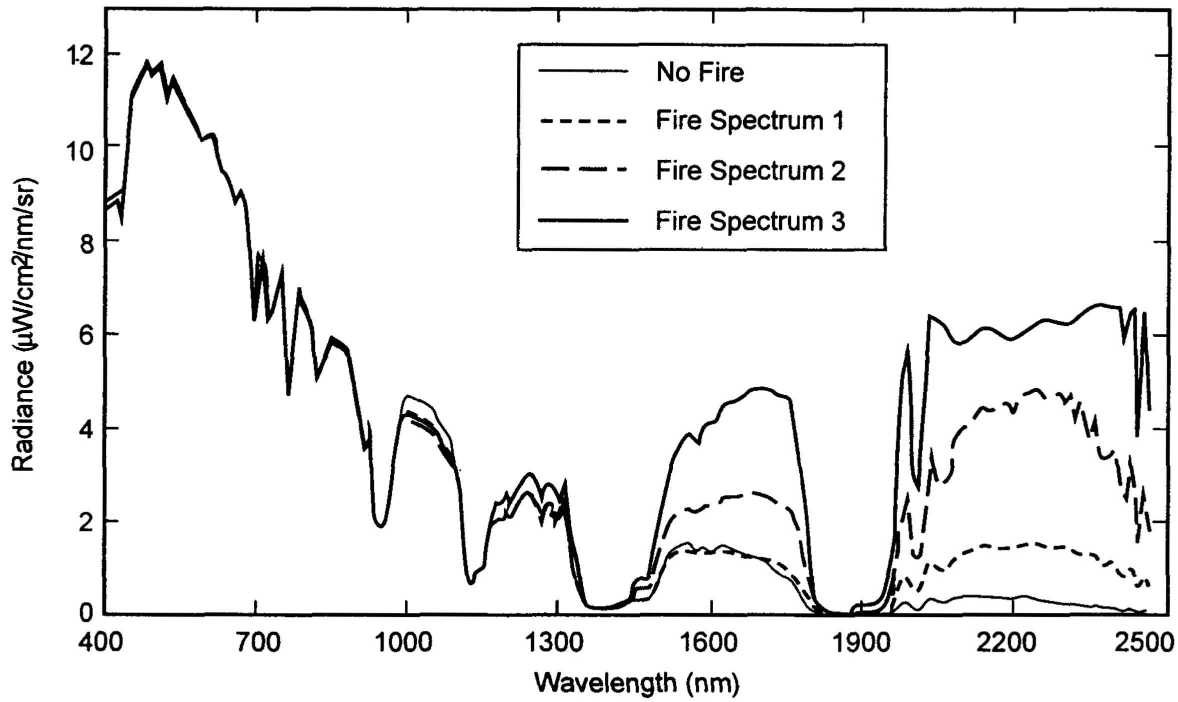

Figure 1. AVIRIS spectra from a fire measured during the 1995 deployment to Brazil. Four spectra are shown. Spectrum 1 is from unburned vegetation. Spectrum 2, 3 and 4 are from active burning areas of increasing intensity. In these fire spectra, the radiance emitted by the fire dominates the 2000 to 2500 nm spectral range.

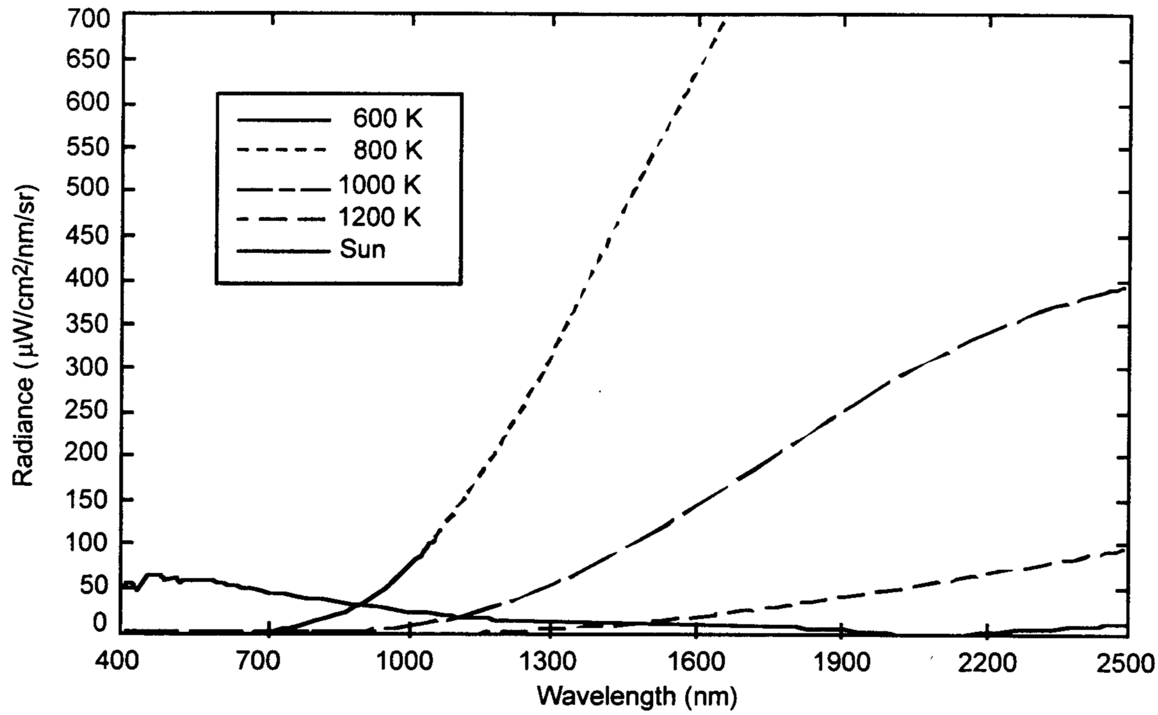

Figure 2. Planck function modeled radiance spectra from fires at several temperatures are shown. The radiance from the sun for a 1.0 reflectance target is also shown.

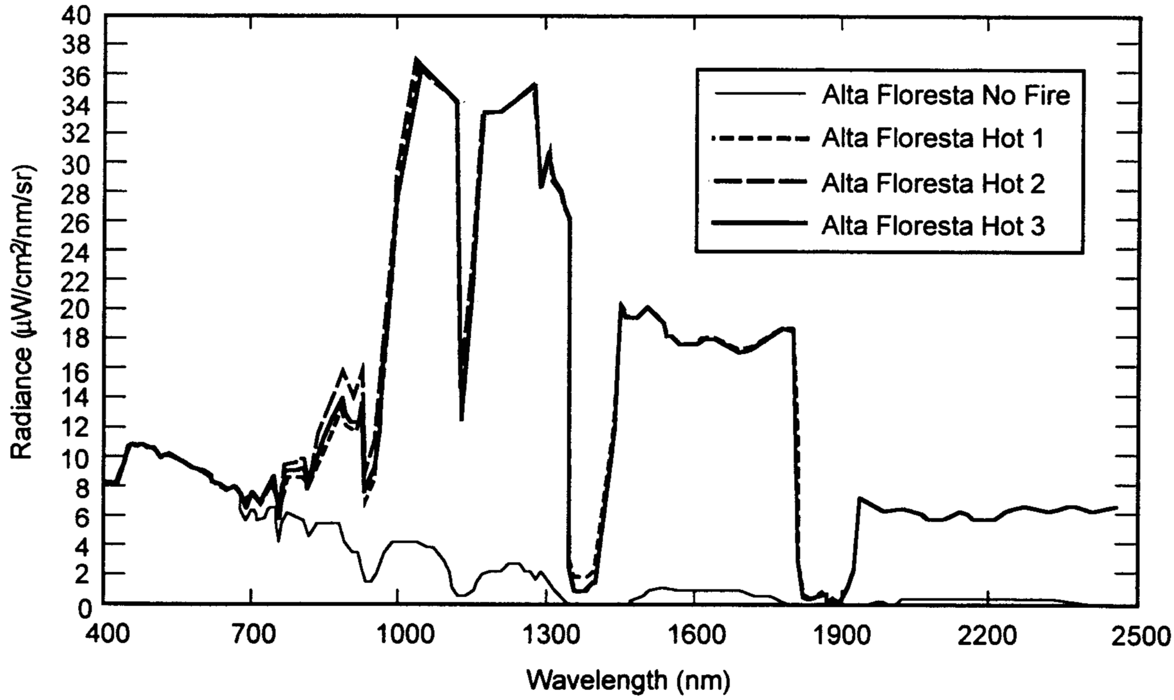

Figure 3. Four spectra from a fire near Alta Floresta acquired on the 23rd of August 1995. The first spectrum is from a non burning area adjacent to the fire. The three fire spectra show a very intense fire with the AVIRIS spectrum saturated near 1000 nm.

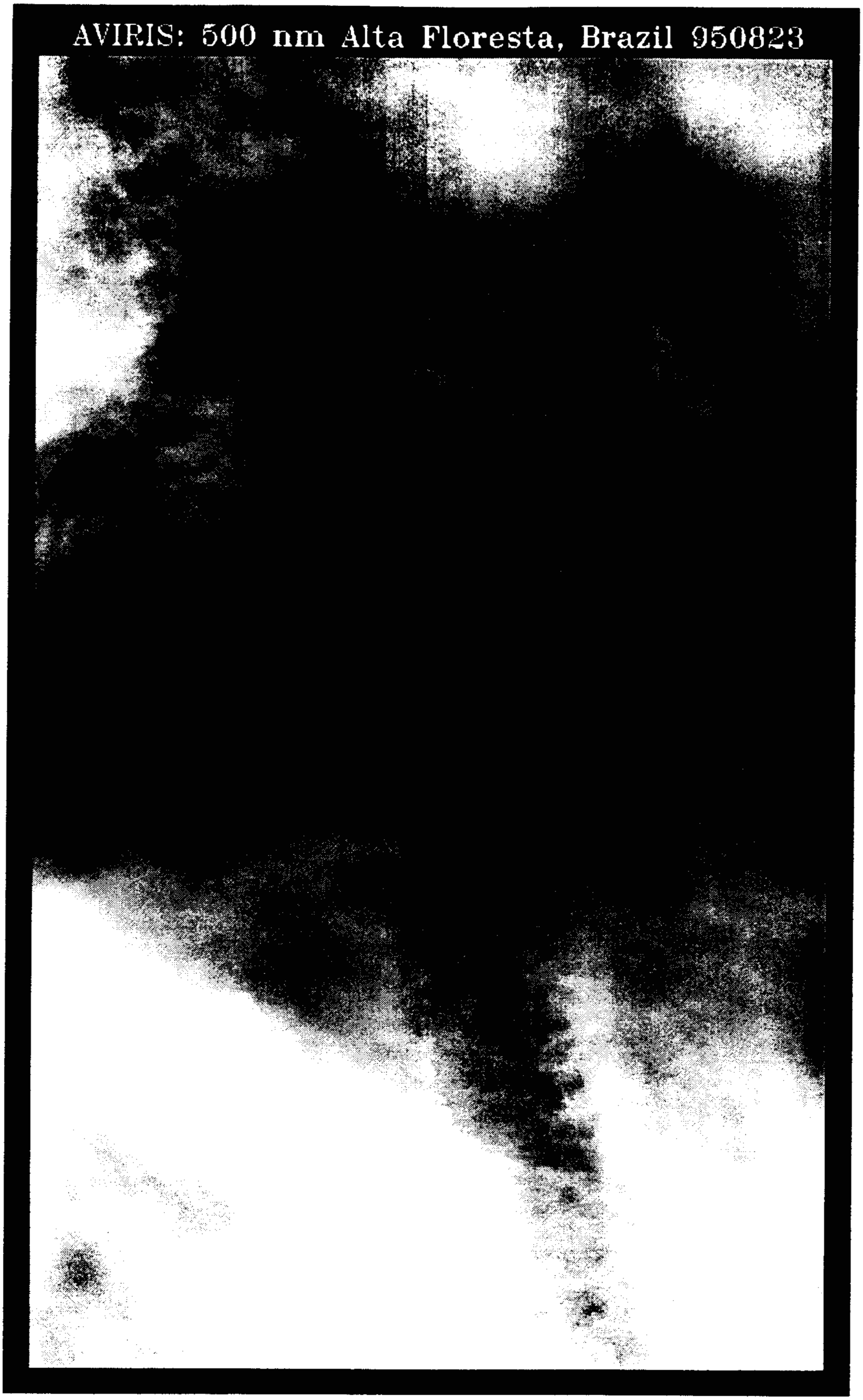

Figure 4. The AVIRIS 500 nm spectral image of the Alta Floresta region. Smoke from fire dominates the entire image.

Figure 5. Alta Floresta AVIRIS spectral image at 1000 nm wavelength. Both solar reflected photons and photons emitted the intense fires penetrate fine particulate smoke. The most intense fire is expressed at the upper right quadrant of the image.

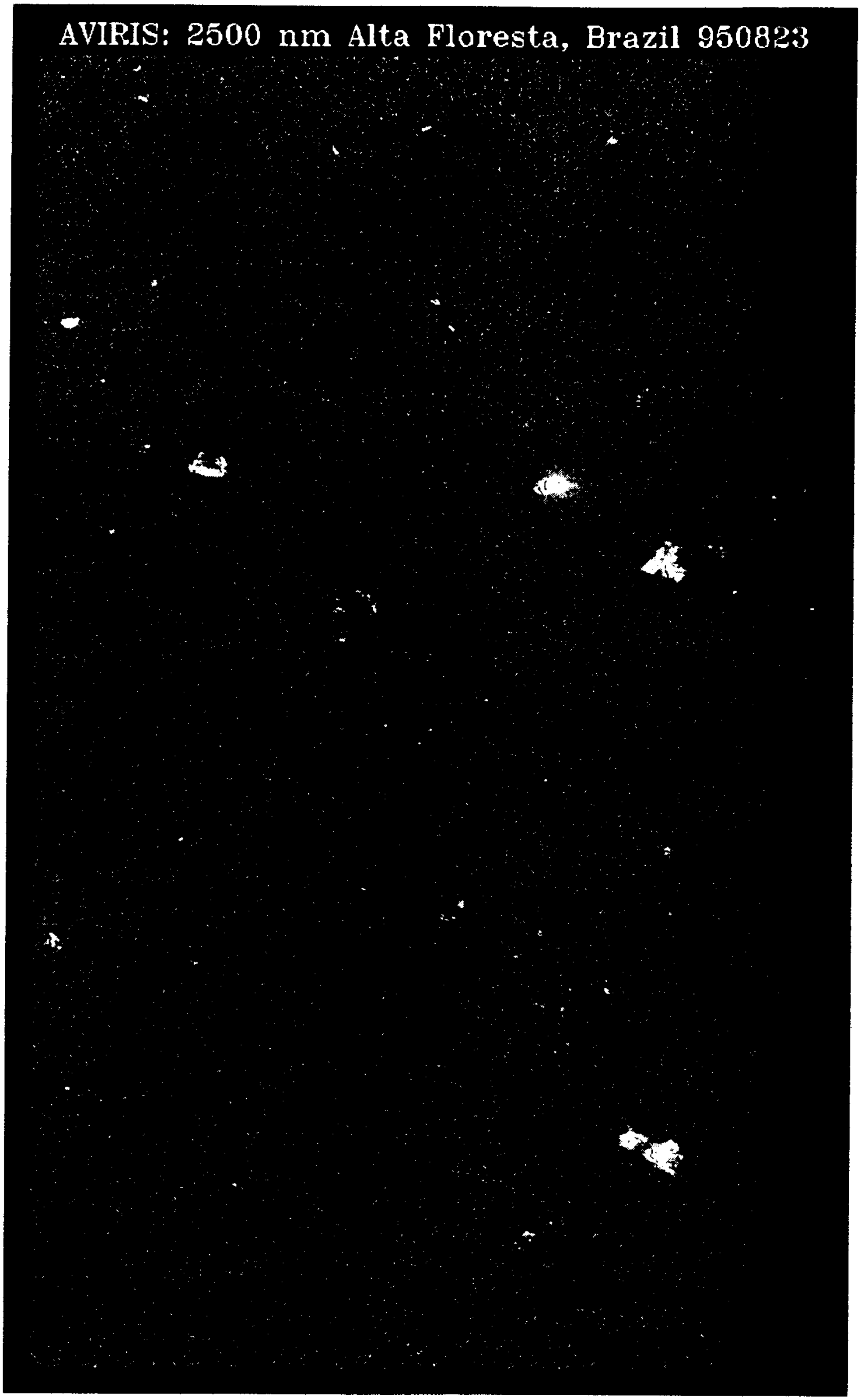

Figure 6. AVIRIS spectral image at 2500 nm wavelength. Only the photons emitted by burning fires penetrate the atmosphere and are measured by AVIRIS.

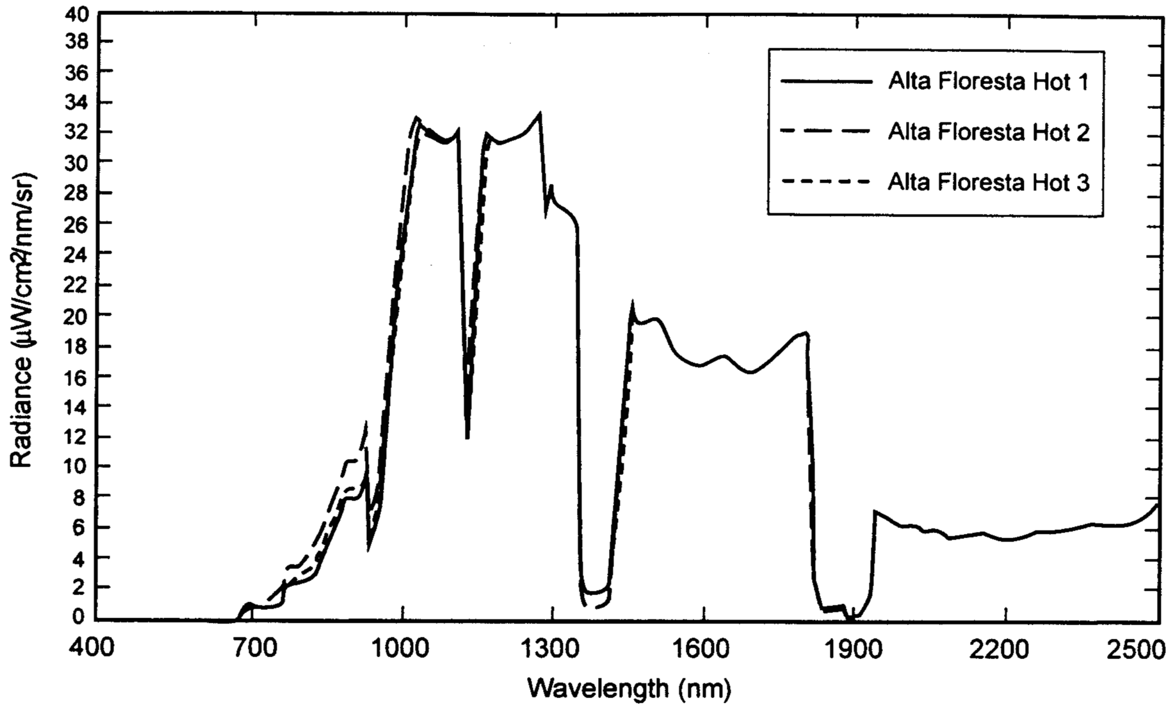

Figure 7. Alta Floresta fire spectra with adjacent non burning spectrum subtracted.

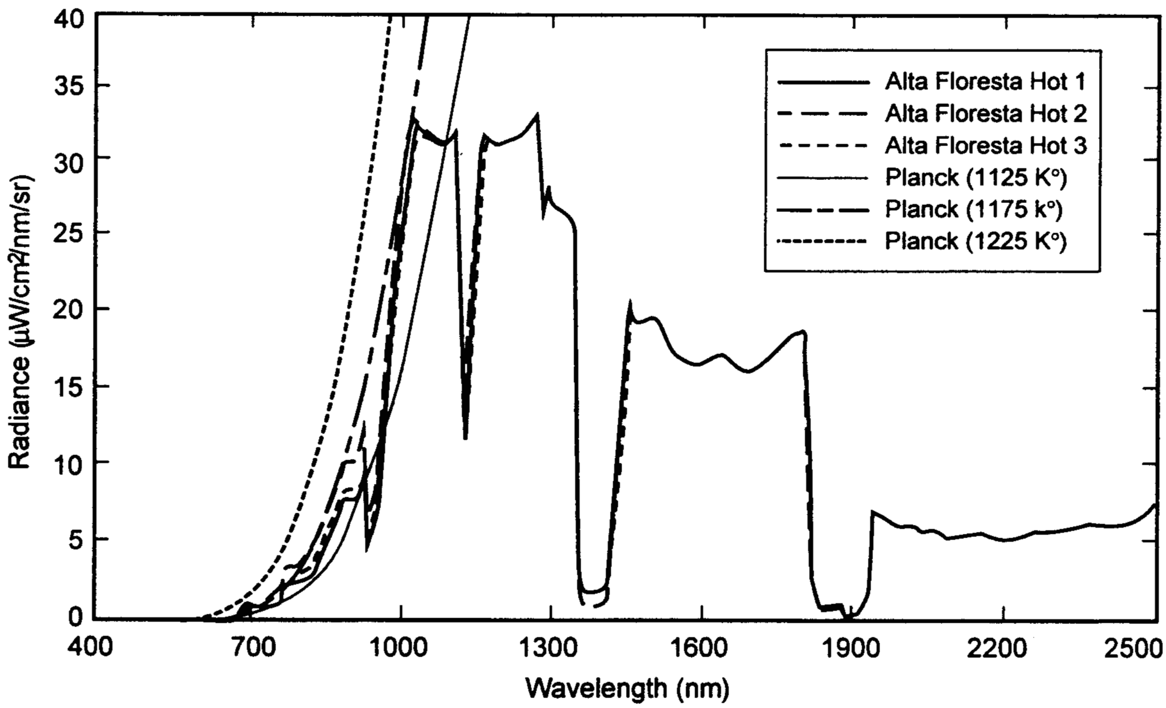

Figure 8. Planck function fit to solar compensated spectra. This gives an initial minimum high temperature of 1175 K.

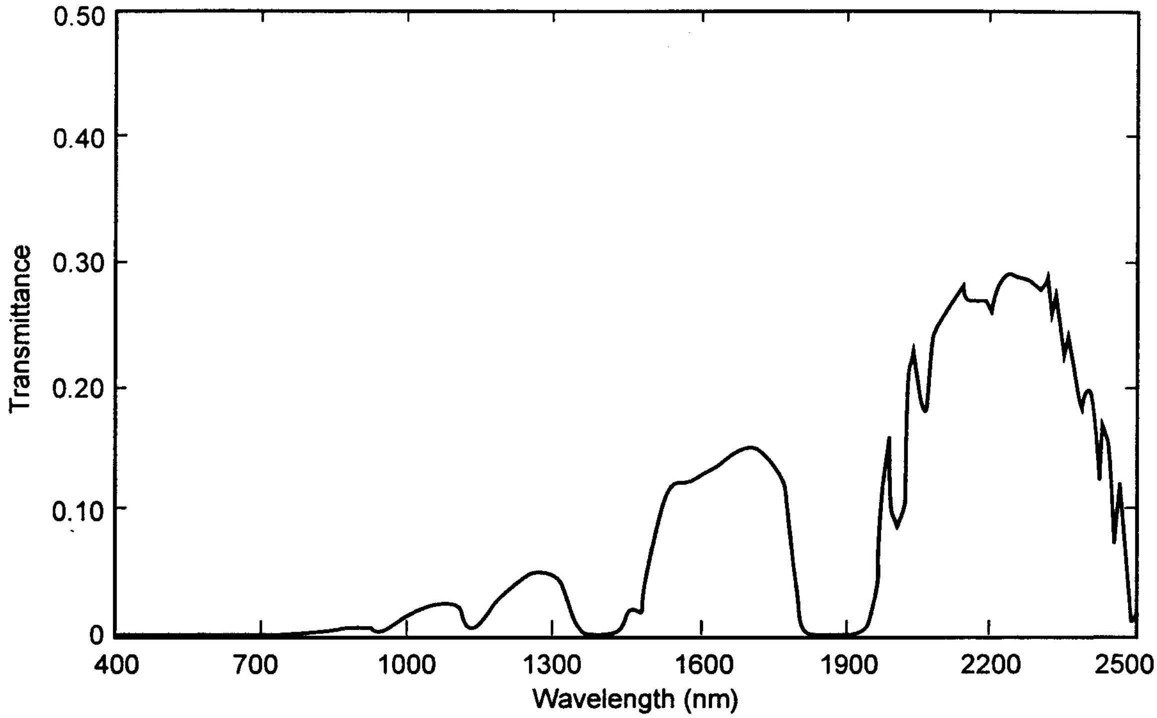

Figure 9. Calculated transmittance for the smoky atmosphere of the Alta Floresta data set.

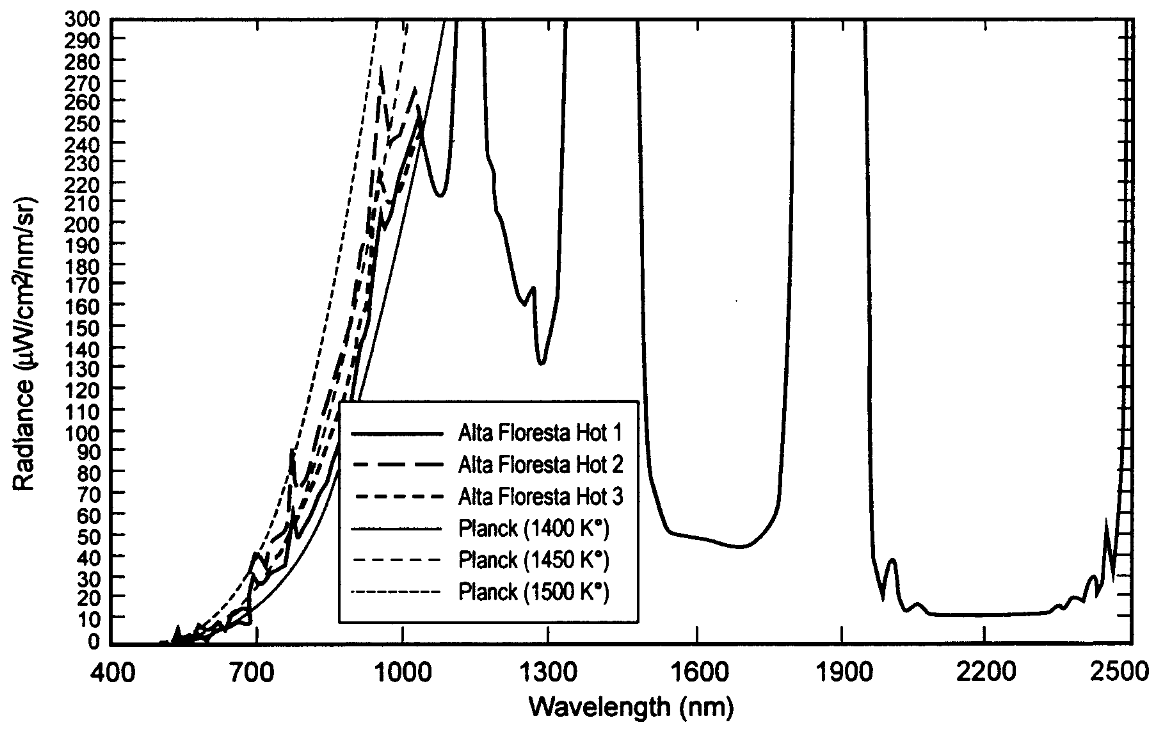

Figure 10. Transmittance compensated spectra and fit to plank functions. This gives an estimate of 1450 K for the minimum high temperature for these spectra.